

METHODS FOR TREATING PAIN AND FOR TREATING A MEDICATION OVERUSE DISORDER

by

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BACKGROUND

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The present invention relates to methods for treating pain. In particular, the present invention relates to use of a botulinum toxin to prevent headaches and to treat an acute pain alleviation medication disorder.

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Many, if not most ailments of the body cause pain. Generally pain is experienced when the free nerve endings which constitute the pain receptors in the skin as well as in certain internal tissues are subjected to mechanical, thermal, chemical or other noxious stimuli. The pain
20 receptors can transmit signals along afferent neurons into the central nervous system and thence to the brain.

The causes of pain can include inflammation, injury, disease, muscle spasm and the onset of a neuropathic event or syndrome. Ineffectively
25 treated pain can be devastating to the person experiencing it by limiting function, reducing mobility, complicating sleep, and dramatically interfering with the quality of life.

A muscle spasm can led to stimulation of mechanosensitive pain
30 receptors thereby causing a sensation of pain. Thus, pain can arise from or be due to a muscle spasm. Additionally, the spasm can indirectly stimulate the pain receptors by compressing onto blood

vessels, causing ischemia in the tissue, which in turn releases pain inducing substances that stimulate pain receptors to cause pain sensations. Furthermore, a muscle spasm can cause a localized pH reduction which can be perceived as or which can engender pain signals. Hence, pain can be a secondary effect of a muscle spasm or muscle hypertonicity.

Inflammatory pain can occur when tissue is damaged, as can result from surgery or due to an adverse physical, chemical or thermal event or to infection by a biologic agent. When a tissue is damaged, a host of endogenous pain inducing substances, for example bradykinin and histamine can be released from the injured tissue. The pain inducing substances can bind to receptors on the sensory nerve terminals and thereby initiate afferent pain signals.

Additionally, pain inducing substances can be released from nociceptive afferent terminals, and neuropeptides released from sensory terminals can accentuate an inflammatory response. Thus, during inflammation there can be a sprouting of peptidergic peripheral fibers and an increased content of peptide, with many fibers showing a coexistence of substance P (SP) and calcitonin gene related peptide (CGRP). Substance P can induce contraction of endothelial cells, which in turn causes plasma extravasation to allow other substances (bradykinin, ATP, histamine) to gain access to the site of injury and the afferent nerve terminals. Substance P release by the sensory nerve terminal can also degranulate mast cell. This process has been considered to be an important factor in neurogenic inflammation due to the release of inflammatory mediators such as histamine and serotonin and the release of proteolytic enzymes which catalyze the production of bradykinin. CGRP apparently does not produce plasma extravasation but is a powerful vasodilator and also act synergistically with SP and other inflammatory mediators to enhance plasma extravasation. All the

above listed inflammatory mediators can either sensitize nociceptors or produce pain.

After activation of the primary sensory afferent neurons the next step
5 in the transduction of sensory signals can be activation of projection
neurons, which carry the signal, via the spinothalamic tract, to higher
parts of the central nervous system such as the thalamic nuclei. The
cell bodies of these neurons (other than those related to the cranial
10 nerves) are located in the dorsal horn of the spinal cord. Here also one
can find the synapses between the primary afferents and the projection
neurons. The dorsal horn is organized into a series of laminae that are
stacked, with lamina I being most dorsal followed by lamina II, etc. The
different classes of primary afferents make synapses in different
15 laminae. For cutaneous primary afferents, C-fibers make synapses in
laminae I and II, A delta-fibers in laminae I, II, and V, and A beta-fibers
in laminae III, IV, and V. Deeper laminae (V-VII, X) are thought to be
involved in the sensory pathways arriving from deeper tissues such as
muscles and the viscera.

20 The predominant neurotransmitters at the synapses between primary
afferent neurons and projection neurons are substance P, glutamate,
CGRP and neuropeptide Y. The efficiency of transmission of these
synapses can be altered via descending pathways and by local
interneurons in the spinal cord. These modulatory neurons can release
25 a number of mediators that are either inhibitory (e.g. opioid peptides,
glycine) or excitatory (e.g. nitric oxide, cholecystokinin), to provide a
mechanism for enhancing or reducing awareness of sensations.

Although inflammatory pain is generally reversible and subsides
30 when the injured tissue has been repaired or the pain inducing stimulus
removed, present methods for treating inflammatory pain have many
drawbacks and deficiencies. Thus, the typical oral, parenteral or topical

administration of an analgesic drug to treat the symptoms of pain or of, for example, an antibiotic to treat inflammatory pain causation factors can result in widespread systemic distribution of the drug and undesirable side effects. Additionally, current therapy for inflammatory pain suffers from short drug efficacy durations which necessitate frequent drug re-administration with possible resulting drug resistance, antibody development and/or drug dependence and addiction, all of which are unsatisfactory. Furthermore, frequent drug administration increases the expense of the regimen to the patient and can require the patient to remember to adhere to a dosing schedule.

Examples of treatments for inflammation and muscle pain include non-steroidal anti-inflammatory drugs (NSAIDS), including aspirin and ibuprofen; and opioids, such as morphine.

NSAIDs alleviate pain by inhibiting the production of prostaglandins released by damaged tissues. Prostaglandins have been shown to be peripheral mediators of pain and inflammation, as in arthritic diseases, and a reduction in their concentration provides relief to patients. It has been suggested that prostaglandins are involved in the mediation of pain in the spinal cord and the brain, which may explain the analgesic effects of NSAIDs in some pain states that do not involve inflammation or peripheral tissue damage. However, prostaglandins are only one of several mediators of pain. As such, NSAIDs have a ceiling of activity above which increasing doses do not give more pain relief. Furthermore, they have side effects that limit their usefulness. For example, NSAIDs can cause irritation of the gastro-intestinal tract and prolonged use may lead to the development of extensive ulceration of the gut. This is particularly true in elderly patients who frequently use NSAIDs for their arthritis conditions.

The therapeutic actions of opioids are in the spinal cord. Opioids

inhibit the efficiency of neurotransmission between the primary sensory afferents (principally C-fibers) and the projection neurons. They achieve this by causing a prolonged hyperpolarization of both elements of these synapses. The use of opioids is effective in alleviating most types of acute pain and chronic malignant pain. There are, however, a number of chronic malignant pain conditions which are partly or completely refractory to opioid analgesia, particularly those which involve nerve compression, e.g. by tumor formation. Unfortunately opioids also have unwanted side-effects including: (1) depression of the respiratory system, (2) constipation, and (3) psychoactive effects including sedation and euphoria. These side effects occur at doses similar to those that produce analgesia and therefore limit the doses that can be given to patients. Additionally, opioids such as morphine and heroin are well-known drugs of abuse that lead to physical dependence, which also involves the development of tolerance. With the development of tolerance, the dose of a drug required to produce the same analgesic effect increases with time. This may lead to a condition in which the doses required to alleviate the pain are life-threatening due to previously mentioned side-effects.

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Although pain arising from inflammation and muscle spasm can be initiated by mechanical or chemical stimulation of the primary sensory neuron free terminal, neuropathic pain does not require an initial stimulus to the peripheral, free nerve terminal. Neuropathic pain is a persistent or chronic pain syndrome that can result from damage to the nervous system, the peripheral nerves, the dorsal root ganglion, dorsal root, or to the central nervous system.

Neuropathic pain syndromes include allodynia, various neuralgias such as post herpetic neuralgia and trigeminal neuralgia, phantom pain, and complex regional pain syndromes, such as reflex sympathetic

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dystrophy and causalgia. Causalgia is often characterized by spontaneous burning pain combined with hyperalgesia and allodynia.

Unfortunately, there is no existing method for adequately, predictably
5 and specifically treating established neuropathic pain (Woolf C. et al.,
Neuropathic Pain: Aetiology, Symptoms, Mechanisms, and
Management, Lancet 1999; 353: 1959-64) as present treatment
methods for neuropathic pain consists of merely trying to help the
patient cope through psychological or occupational therapy, rather than
10 by reducing or eliminating the pain experienced.

For example, current methods to treat neuropathic pain include
administration of local anesthetic blocks targeted to trigger points,
peripheral nerves, plexi, dorsal roots, and to the sympathetic nervous
15 system. However, these treatments have only short-lived
antinociceptive effects. Additionally, longer lasting analgesic treatment
methods, such as blocks by phenol injection or cryotherapy raise a
considerable risk of irreversible functional impairment. Furthermore,
chronic epidural or intrathecal (collectively "intraspinale") administration of
20 drugs such as clonidine, steroids, opioids or midazolam have significant
side effects and questionable efficacy.

Headache

A headache is a pain in the head, such as in the scalp, face,
25 forehead or neck. A headache can be a primary headache or a
secondary headache. A primary headache is a headache which is not
caused by another condition. Contrarily, a secondary headache is due
to a disease or medical condition, such as an illness, infection, injury,
stroke or other abnormality. Thus, with a secondary headache there is
30 an underlying disorder that produces the headache as a symptom of
that underlying disorder. Tension headache is the most common type of

primary headache and tension headaches account for about 90% of all headaches. A tension headache is often experienced in the forehead, in the back of the head and neck, or in both regions. It has been described as a tight feeling, as if the head were in a vise. Soreness in the shoulders or neck is common. Nausea is uncommon with a tension headache.

Migraine headaches are recurrent headaches that may be unilateral or bilateral. Migraine headaches may occur with or without a prodrome. The aura of a migraine may consist of neurologic symptoms, such as dizziness, tinnitus, scotomas, photophobia, or visual scintillations (eg, bright zigzag lines). Migraines without aura are the most common, accounting for more than 80% of all migraines.

An estimated 10-20% of the population suffers from migraine headaches. An estimated 6% of men and 15-17% of women in the United States have migraine. Migraines most commonly are found in women, with a 3:1 female-to-male ratio.

About 2% of all headaches are secondary headaches. For example, a cervicogenic headache is a headache which is due to a neck problem, such as an abnormality of neck muscles, which can result from prolonged poor posture, arthritis, injuries of the upper spine, or from a cervical spine disorder. Sinus headache is another type of secondary headache. A sinus headache can be caused by inflammation and/or infection in the paranasal sinuses.

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Medication Overuse Headache Disorder

Daily or near-daily headache can affect up to 5% of some populations, and it is believed that chronic overuse of headache drugs may account for half of this phenomenon. All simple analgesics, and probably non-steroidal anti-inflammatory drugs, ergotamine, and

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triptans, are implicated. Medication overuse headache affects more women than men (5:1) and some children.

The regular intake of three or more analgesic tablets daily or
5 narcotics or ergotamine on more than two days a week to control or
alleviate a headache has been suggested as a medication overuse
headache definition. A common and probably key factor in medication
overuse headache is pre-emptive use of drugs, in anticipation of rather
than for a headache. Medication overuse headache usually does not
10 develop when analgesics are regularly taken for another indication, such
as chronic backache or rheumatic disease, that is the headache must
be present to begin with.

A presumptive diagnosis of medication overuse headache is based
15 on symptoms and a detailed history of drug use, including over the
counter drugs. Many patients with medication overuse headache
disorder use large quantities of drug: 35 doses a week on average in
one study, and six different agents. Sooner or later, such patients seek
prescriptions for "something stronger," bringing them to the general
20 practitioner's attention. However, medication overuse headache is
typically confirmed only when symptoms improve after drugs are
withdrawn. The headache is oppressive, present, and often at its worst
on awakening in the morning. It can be increased after physical
exertion. Associated nausea and vomiting are rarely pronounced. A
25 typical history begins with episodic headache up to years earlier (more
commonly migraine than tension-type headache), treated with an
analgesic or other acute medication. Over time, headache episodes
become more frequent, as does drug intake, until both are daily. In the
end stage, which not all patients reach, headache persists all day,
30 fluctuating with medication use repeated every few hours. This evolution
occurs over a few weeks or much longer, depending largely but not
solely on the medication taken.

The International Headache Society defines medication overuse headache (MOH) as a chronic headache (headache frequency > 15 days per month) after the intake of analgesics or ergots (more than 15 times per month for at least 3 months), which disappears after withdrawal therapy. It has been described as a self-sustaining, rhythmic, headache medication cycle characterized by daily or near daily headache and irresistible and predictable use of immediate relief medications. Evidence supporting the existence of MOH is widely published in the medical literature.

The pathogenesis of MOH has not been fully elucidated. Some evidence suggests that up regulation of serotonin receptors and subsequent reduction in serotonin levels, which normalize upon cessation of chronic analgesic use, may play a role. The following have also been implicated in the development of MOH: endorphin suppression, central opioid receptor impairment, impaired suppression or downregulation of an already partly suppressed or abnormal antinociceptive system, alterations in density and function of postsynaptic neuronal receptors, and activation of nociceptive "on-cells" in the ventral medulla that facilitate nociceptive reflex responses. A common presentation is a patient with a history of episodic migraine with or without aura, who complains of increased headache frequency and the development of interparoxysmal tension-type headache, that eventually transforms into a daily or near-daily headache lasting for prolonged periods. Patients may alternate between migraine-type and tension-type headaches during this period. Behavioral and psychiatric comorbidities may also be present and are complicating factors. It is common for patients to underestimate their use of analgesics and to use multiple types of agents concomitantly. Initially, pain relief provides negative reinforcement, and in some cases changes in mood incurred from barbiturate and caffeine-containing analgesics, may provide

positive reinforcement, resulting in excessive use. Tolerance, characterized by increasing consumption without regard to potential adverse outcomes, and withdrawal symptoms upon abrupt discontinuation, often ensue and result in increased headache frequency and severity with a decrease in analgesic efficacy. Concomitant preventive medications are relatively ineffective, while the patient is using excessive amounts of abortive agents and complete discontinuation of headache medication is the treatment of choice. Detoxification is usually conducted slowly over as many as 8 to 12 weeks and in the most severe cases, may warrant hospitalization.

Medication overuse to treat headache ("MOH") has been recently recognized as a unique disorder diagnosis of the International Classification of Headache Disorders, 2nd edition, published in supplement 1, Cephalgia 2004: volume 24, pages 94-95, wherein, significantly, it is stated that patients with a MOH disorder rarely respond to other preventive medications while they are overusing their acute pain medications.

Botulinum Toxin

The genus Clostridium has more than one hundred and twenty seven species, grouped according to their morphology and functions. The anaerobic, gram positive bacterium Clostridium botulinum produces a potent polypeptide neurotoxin, botulinum toxin, which causes a neuromuscular illness in humans and animals referred to as botulism. The spores of Clostridium botulinum are found in soil and can grow in improperly sterilized and sealed food containers of home based canneries, which are the cause of many of the cases of botulism. The effects of botulism typically appear 18 to 36 hours after eating the foodstuffs infected with a Clostridium botulinum culture or spores. The botulinum toxin can apparently pass unattenuated through the lining of the gut and attack peripheral motor neurons. Symptoms of botulinum

toxin intoxication can progress from difficulty walking, swallowing, and speaking to paralysis of the respiratory muscles and death.

Botulinum toxin type A is the most lethal natural biological agent known to man. About 50 picograms of a commercially available botulinum toxin type A (purified neurotoxin complex)¹ is a LD₅₀ in mice (i.e. 1 unit). One unit of BOTOX® contains about 50 picograms (about 56 attomoles) of botulinum toxin type A complex. Interestingly, on a molar basis, botulinum toxin type A is about 1.8 billion times more lethal than diphtheria, about 600 million times more lethal than sodium cyanide, about 30 million times more lethal than cobra toxin and about 12 million times more lethal than cholera. Singh, *Critical Aspects of Bacterial Protein Toxins*, pages 63-84 (chapter 4) of *Natural Toxins II*, edited by B.R. Singh et al., Plenum Press, New York (1976) (where the stated LD₅₀ of botulinum toxin type A of 0.3 ng equals 1 U is corrected for the fact that about 0.05 ng of BOTOX® equals 1 unit). One unit (U) of botulinum toxin is defined as the LD₅₀ upon intraperitoneal injection into female Swiss Webster mice weighing 18 to 20 grams each.

Seven generally immunologically distinct botulinum neurotoxins have been characterized, these being respectively botulinum neurotoxin serotypes A, B, C₁, D, E, F and G each of which is distinguished by neutralization with type-specific antibodies. The different serotypes of botulinum toxin vary in the animal species that they affect and in the severity and duration of the paralysis they evoke. For example, it has been determined that botulinum toxin type A is 500 times more potent, as measured by the rate of paralysis produced in the rat, than is botulinum toxin type B. Additionally, botulinum toxin type B has been determined to be non-toxic in primates at a dose of 480 U/kg which is about 12 times the primate LD₅₀ for botulinum toxin type A. Moyer E et al., *Botulinum Toxin Type B: Experimental and Clinical Experience*,

¹ Available from Allergan, Inc., of Irvine, California under the tradename BOTOX® in 100 unit vials)

being chapter 6, pages 71-85 of "Therapy With Botulinum Toxin", edited by Jankovic, J. et al. (1994), Marcel Dekker, Inc. Botulinum toxin apparently binds with high affinity to cholinergic motor neurons, is translocated into the neuron and blocks the release of acetylcholine.

- 5 Additional uptake can take place through low affinity receptors, as well as by phagocytosis and pinocytosis.

Regardless of serotype, the molecular mechanism of toxin intoxication appears to be similar and to involve at least three steps or stages. In the first step of the process, the toxin binds to the presynaptic membrane of the target neuron through a specific interaction between the heavy chain, H chain, and a cell surface receptor; the receptor is thought to be different for each type of botulinum toxin and for tetanus toxin. The carboxyl end segment of the H chain, H_C, appears to be
15 important for targeting of the toxin to the cell surface.

In the second step, the toxin crosses the plasma membrane of the poisoned cell. The toxin is first engulfed by the cell through receptor-mediated endocytosis, and an endosome containing the toxin is formed.
20 The toxin then escapes the endosome into the cytoplasm of the cell. This step is thought to be mediated by the amino end segment of the H chain, H_N, which triggers a conformational change of the toxin in response to a pH of about 5.5 or lower. Endosomes are known to possess a proton pump which decreases intra-endosomal pH. The
25 conformational shift exposes hydrophobic residues in the toxin, which permits the toxin to embed itself in the endosomal membrane. The toxin (or at a minimum the light chain) then translocates through the endosomal membrane into the cytoplasm.

30 The last step of the mechanism of botulinum toxin activity appears to involve reduction of the disulfide bond joining the heavy chain, H chain, and the light chain, L chain. The entire toxic activity of botulinum and

tetanus toxins is contained in the L chain of the holotoxin; the L chain is a zinc (Zn^{++}) endopeptidase which selectively cleaves proteins essential for recognition and docking of neurotransmitter-containing vesicles with the cytoplasmic surface of the plasma membrane, and fusion of the vesicles with the plasma membrane. Tetanus neurotoxin, botulinum toxin types B, D, F, and G cause degradation of synaptobrevin (also called vesicle-associated membrane protein (VAMP)), a synaptosomal membrane protein. Most of the VAMP present at the cytoplasmic surface of the synaptic vesicle is removed as a result of any one of these cleavage events. Botulinum toxin serotype A and E cleave SNAP-25. Botulinum toxin serotype C_1 was originally thought to cleave syntaxin, but was found to cleave syntaxin and SNAP-25. Each of the botulinum toxins specifically cleaves a different bond, except botulinum toxin type B (and tetanus toxin) which cleave the same bond. Each of these cleavages block the process of vesicle-membrane docking, thereby preventing exocytosis of vesicle content.

Botulinum toxins have been used in clinical settings for the treatment of neuromuscular disorders characterized by hyperactive skeletal muscles (i.e. motor disorders). In 1989 a botulinum toxin type A complex has been approved by the U.S. Food and Drug Administration for the treatment of blepharospasm, strabismus and hemifacial spasm. Subsequently, a botulinum toxin type A was also approved by the FDA for the treatment of cervical dystonia and for the treatment of glabellar lines, and a botulinum toxin type B was approved for the treatment of cervical dystonia. Non-type A botulinum toxin serotypes apparently have a lower potency and/or a shorter duration of activity as compared to botulinum toxin type A. Clinical effects of peripheral intramuscular botulinum toxin type A are usually seen within one week of injection. The typical duration of symptomatic relief from a single intramuscular injection of botulinum toxin type A averages about three months, although significantly longer periods of therapeutic activity have been

reported.

Although all the botulinum toxins serotypes apparently inhibit release of the neurotransmitter acetylcholine at the neuromuscular junction, they do so by affecting different neurosecretory proteins and/or cleaving these proteins at different sites. For example, botulinum types A and E both cleave the 25 kiloDalton (kD) synaptosomal associated protein (SNAP-25), but they target different amino acid sequences within this protein. Botulinum toxin types B, D, F and G act on vesicle-associated protein (VAMP, also called synaptobrevin), with each serotype cleaving the protein at a different site. Finally, botulinum toxin type C₁ has been shown to cleave both syntaxin and SNAP-25. These differences in mechanism of action may affect the relative potency and/or duration of action of the various botulinum toxin serotypes. Apparently, a substrate for a botulinum toxin can be found in a variety of different cell types. See e.g. *Biochem J* 1;339 (pt 1):159-65:1999, and *Mov Disord*, 10(3):376:1995 (pancreatic islet B cells contains at least SNAP-25 and synaptobrevin).

The molecular weight of the botulinum toxin protein molecule, for all seven of the known botulinum toxin serotypes, is about 150 kD. Interestingly, the botulinum toxins are released by Clostridial bacterium as complexes comprising the 150 kD botulinum toxin protein molecule along with associated non-toxin proteins. Thus, the botulinum toxin type A complex can be produced by Clostridial bacterium as 900 kD, 500 kD and 300 kD forms. Botulinum toxin types B and C₁ is apparently produced as only a 700 kD or 500 kD complex. Botulinum toxin type D is produced as both 300 kD and 500 kD complexes. Finally, botulinum toxin types E and F are produced as only approximately 300 kD complexes. The complexes (i.e. molecular weight greater than about 150 kD) are believed to contain a non-toxin hemagglutinin protein and a non-toxin and non-toxic nonhemagglutinin protein. These two non-toxin

proteins (which along with the botulinum toxin molecule comprise the relevant neurotoxin complex) may act to provide stability against denaturation to the botulinum toxin molecule and protection against digestive acids when toxin is ingested. Additionally, it is possible that
5 the larger (greater than about 150 kD molecular weight) botulinum toxin complexes may result in a slower rate of diffusion of the botulinum toxin away from a site of intramuscular injection of a botulinum toxin complex.

In vitro studies have indicated that botulinum toxin inhibits potassium
10 cation induced release of both acetylcholine and norepinephrine from primary cell cultures of brainstem tissue. Additionally, it has been reported that botulinum toxin inhibits the evoked release of both glycine and glutamate in primary cultures of spinal cord neurons and that in brain synaptosome preparations botulinum toxin inhibits the release of
15 each of the neurotransmitters acetylcholine, dopamine, norepinephrine (Habermann E., et al., *Tetanus Toxin and Botulinum A and C Neurotoxins Inhibit Noradrenaline Release From Cultured Mouse Brain*, J Neurochem 51(2);522-527:1988) CGRP, substance P and glutamate (Sanchez-Prieto, J., et al., *Botulinum Toxin A Blocks Glutamate*
20 *Exocytosis From Guinea Pig Cerebral Cortical Synaptosomes*, Eur J. Biochem 165;675-681:1897.. Thus, when adequate concentrations are used, stimulus-evoked release of most neurotransmitters is blocked by botulinum toxin. See e.g. Pearce, L.B., *Pharmacologic Characterization of Botulinum Toxin For Basic Science and Medicine*, Toxicon
25 35(9);1373-1412 at 1393; Bigalke H., et al., *Botulinum A Neurotoxin Inhibits Non-Cholinergic Synaptic Transmission in Mouse Spinal Cord Neurons in Culture*, Brain Research 360;318-324:1985; Habermann E., *Inhibition by Tetanus and Botulinum A Toxin of the release of [³H]Noradrenaline and [³H]GABA From Rat Brain Homogenate*,
30 *Experientia* 44;224-226:1988, Bigalke H., et al., *Tetanus Toxin and Botulinum A Toxin Inhibit Release and Uptake of Various Transmitters, as Studied with Particulate Preparations From Rat Brain and Spinal*

Cord, Naunyn-Schmiedeberg's Arch Pharmacol 316;244-251:1981, and; Jankovic J. et al., *Therapy With Botulinum Toxin*, Marcel Dekker, Inc., (1994), page 5.

5 Botulinum toxin type A can be obtained by establishing and growing cultures of *Clostridium botulinum* in a fermenter and then harvesting and purifying the fermented mixture in accordance with known procedures. All the botulinum toxin serotypes are initially synthesized as inactive single chain proteins which must be cleaved or nicked by proteases to
10 become neuroactive. The bacterial strains that make botulinum toxin serotypes A and G possess endogenous proteases and serotypes A and G can therefore be recovered from bacterial cultures in predominantly their active form. In contrast, botulinum toxin serotypes C₁, D and E are synthesized by nonproteolytic strains and are therefore
15 typically unactivated when recovered from culture. Serotypes B and F are produced by both proteolytic and nonproteolytic strains and therefore can be recovered in either the active or inactive form. However, even the proteolytic strains that produce, for example, the botulinum toxin type B serotype only cleave a portion of the toxin
20 produced. The exact proportion of nicked to unnicked molecules depends on the length of incubation and the temperature of the culture. Therefore, a certain percentage of any preparation of, for example, the botulinum toxin type B toxin is likely to be inactive, possibly accounting for the known significantly lower potency of botulinum toxin type B as
25 compared to botulinum toxin type A. The presence of inactive botulinum toxin molecules in a clinical preparation will contribute to the overall protein load of the preparation, which has been linked to increased antigenicity, without contributing to its clinical efficacy. Additionally, it is known that botulinum toxin type B has, upon intramuscular injection, a
30 shorter duration of activity and is also less potent than botulinum toxin type A at the same dose level.

High quality crystalline botulinum toxin type A can be produced from the Hall A strain of *Clostridium botulinum* with characteristics of $\geq 3 \times 10^7$ U/mg, an A_{260}/A_{278} of less than 0.60 and a distinct pattern of banding on gel electrophoresis. The known Shantz process can be used to obtain crystalline botulinum toxin type A, as set forth in Shantz, E.J., et al, *Properties and use of Botulinum toxin and Other Microbial Neurotoxins in Medicine*, Microbiol Rev. 56;80-99:1992. Generally, the botulinum toxin type A complex can be isolated and purified from an anaerobic fermentation by cultivating *Clostridium botulinum* type A in a suitable medium. The known process can also be used, upon separation out of the non-toxin proteins, to obtain pure botulinum toxins, such as for example: purified botulinum toxin type A with an approximately 150 kD molecular weight with a specific potency of $1-2 \times 10^8$ LD₅₀ U/mg or greater; purified botulinum toxin type B with an approximately 156 kD molecular weight with a specific potency of $1-2 \times 10^8$ LD₅₀ U/mg or greater, and; purified botulinum toxin type F with an approximately 155 kD molecular weight with a specific potency of $1-2 \times 10^7$ LD₅₀ U/mg or greater.

Botulinum toxins and/or botulinum toxin complexes can be obtained from List Biological Laboratories, Inc., Campbell, California; the Centre for Applied Microbiology and Research, Porton Down, U.K.; Wako (Osaka, Japan), Metabiologics (Madison, Wisconsin) as well as from Sigma Chemicals of St Louis, Missouri. Pure botulinum toxin can also be used to prepare a pharmaceutical composition.

As with enzymes generally, the biological activities of the botulinum toxins (which are intracellular peptidases) is dependant, at least in part, upon their three dimensional conformation. Thus, botulinum toxin type A is detoxified by heat, various chemicals surface stretching and surface drying. Additionally, it is known that dilution of the toxin complex obtained by the known culturing, fermentation and purification to the

much, much lower toxin concentrations used for pharmaceutical composition formulation results in rapid detoxification of the toxin unless a suitable stabilizing agent is present. Dilution of the toxin from milligram quantities to a solution containing nanograms per milliliter presents significant difficulties because of the rapid loss of specific toxicity upon such great dilution. Since the toxin may be used months or years after the toxin containing pharmaceutical composition is formulated, the toxin can be stabilized with a stabilizing agent such as albumin and gelatin.

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A commercially available botulinum toxin containing pharmaceutical composition is sold under the trademark BOTOX[®] (available from Allergan, Inc., of Irvine, California). BOTOX[®] consists of a purified botulinum toxin type A complex, albumin and sodium chloride packaged in sterile, vacuum-dried form. The botulinum toxin type A is made from a culture of the Hall strain of *Clostridium botulinum* grown in a medium containing N-Z amine and yeast extract. The botulinum toxin type A complex is purified from the culture solution by a series of acid precipitations to a crystalline complex consisting of the active high molecular weight toxin protein and an associated hemagglutinin protein. The crystalline complex is re-dissolved in a solution containing saline and albumin and sterile filtered (0.2 microns) prior to vacuum-drying. The vacuum-dried product is stored in a freezer at or below -5°C. BOTOX[®] can be reconstituted with sterile, non-preserved saline prior to intramuscular injection. Each vial of BOTOX[®] contains about 100 units (U) of *Clostridium botulinum* toxin type A purified neurotoxin complex, 0.5 milligrams of human serum albumin and 0.9 milligrams of sodium chloride in a sterile, vacuum-dried form without a preservative.

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To reconstitute vacuum-dried BOTOX[®], sterile normal saline without a preservative; (0.9% Sodium Chloride Injection) is used by drawing up the proper amount of diluent in the appropriate size syringe. Since

BOTOX® may be denatured by bubbling or similar violent agitation, the diluent is gently injected into the vial. For sterility reasons BOTOX® is preferably administered within four hours after the vial is removed from the freezer and reconstituted. During these four hours, reconstituted
5 BOTOX® can be stored in a refrigerator at about 2° C. to about 8°C. Reconstituted, refrigerated BOTOX® has been reported to retain its potency for at least about two weeks. *Neurology*, 48:249-53:1997.

It has been reported that botulinum toxin type A has been used in
10 clinical settings as follows:

- (1) about 75-125 units of BOTOX® per intramuscular injection (multiple muscles) to treat cervical dystonia;
- (2) 5-10 units of BOTOX® per intramuscular injection to treat glabellar lines (brow furrows) (5 units injected intramuscularly into the procerus
15 muscle and 10 units injected intramuscularly into each corrugator supercilii muscle);
- (3) about 30-80 units of BOTOX® to treat constipation by intrasphincter injection of the puborectalis muscle;
- (4) about 1-5 units per muscle of intramuscularly injected BOTOX® to
20 treat blepharospasm by injecting the lateral pre-tarsal orbicularis oculi muscle of the upper lid and the lateral pre-tarsal orbicularis oculi of the lower lid.
- (5) to treat strabismus, extraocular muscles have been injected intramuscularly with between about 1-5 units of BOTOX®, the amount
25 injected varying based upon both the size of the muscle to be injected and the extent of muscle paralysis desired (i.e. amount of diopter correction desired).
- (6) to treat upper limb spasticity following stroke by intramuscular injections of BOTOX® into five different upper limb flexor muscles, as
30 follows:
 - (a) flexor digitorum profundus: 7.5 U to 30 U

(b) flexor digitorum sublimus: 7.5 U to 30 U

(c) flexor carpi ulnaris: 10 U to 40 U

(d) flexor carpi radialis: 15 U to 60 U

(e) biceps brachii: 50 U to 200 U. Each of the five indicated muscles
5 has been injected at the same treatment session, so that the patient
receives from 90 U to 360 U of upper limb flexor muscle BOTOX® by
intramuscular injection at each treatment session.

(7) to treat migraine, pericranial injected (injected symmetrically into
glabellar, frontalis and temporalis muscles) injection of 25 U of BOTOX®
10 has showed significant benefit as a prophylactic treatment of migraine
compared to vehicle as measured by decreased measures of migraine
frequency, maximal severity, associated vomiting and acute medication
use over the three month period following the 25 U injection.

15 Additionally, intramuscular botulinum toxin has been used in the
treatment of tremor in patients with Parkinson's disease, although it has
been reported that results have not been impressive. Marjama-Jyons,
J., et al., *Tremor-Predominant Parkinson's Disease*, *Drugs & Aging*
16(4);273-278:2000.

20

It is known that botulinum toxin type A can have an efficacy for up to
12 months (*European J. Neurology* 6 (Supp 4): S111-S1150:1999), and
in some circumstances for as long as 27 months, when used to treat
glands, such as in the treatment of hyperhydrosis . See e.g. Bushara
25 K., *Botulinum toxin and rhinorrhea*, *Otolaryngol Head Neck Surg*
1996;114(3):507, and *The Laryngoscope* 109:1344-1346:1999.
However, the usual duration of an intramuscular injection of Botox® is
typically about 3 to 4 months.

30 The success of botulinum toxin type A to treat a variety of clinical
conditions has led to interest in other botulinum toxin serotypes. Two
commercially available botulinum type A preparations for use in humans

are BOTOX® available from Allergan, Inc., of Irvine, California, and Dysport® available from Beaufour Ipsen, Porton Down, England. A Botulinum toxin type B preparation (MyoBloc®) is available from Elan Pharmaceuticals of San Francisco, California.

5

In addition to having pharmacologic actions at the peripheral location, botulinum toxins may also have inhibitory effects in the central nervous system. Work by Weigand et al, *Nauny-Schmiedeberg's Arch.*

Pharmacol. 1976; 292, 161-165, and Habermann, *Nauny-*

10 *Schmiedeberg's Arch. Pharmacol.* 1974; 281, 47-56 showed that botulinum toxin is able to ascend to the spinal area by retrograde transport. As such, a botulinum toxin injected at a peripheral location, for example intramuscularly, may be retrograde transported to the spinal cord.

15

U.S. Patent No. 5,989,545 discloses that a modified clostridial neurotoxin or fragment thereof, preferably a botulinum toxin, chemically conjugated or recombinantly fused to a particular targeting moiety can be used to treat pain by administration of the agent to the spinal cord.

20

It has been reported that use of a botulinum toxin to treat various spasmodic muscle conditions can result in reduced depression and anxiety, as the muscle spasm is reduced. Murry T., et al., *Spasmodic dysphonia; emotional status and botulinum toxin treatment*, Arch

25 *Otolaryngol* 1994 Mar; 120(3): 310-316; Jahanshahi M., et al., *Psychological functioning before and after treatment of torticollis with botulinum toxin*, J Neurol Neurosurg Psychiatry 1992; 55(3): 229-231.

Additionally, German patent application DE 101 50 415 A1 discusses intramuscular injection of a botulinum toxin to treat depression and
30 related affective disorders.

A botulinum toxin has also been proposed for or has been used to treat skin wounds (U.S. patent 6,447,787), various autonomic nerve dysfunctions (U.S. patent 5,766,605), tension headache, (U.S. patent 6,458,365), migraine headache pain (U.S. patent 5,714,468), sinus
5 headache (U.S. patent application serial number 429069), post-operative pain and visceral pain (U.S. patent 6,464,986), neuralgia pain (U.S. patent application serial number 630,587), hair growth and hair retention (U.S. patent 6,299,893), dental related ailments (U.S. provisional patent application serial number 60/418,789), fibromyalgia
10 (U.S. patent 6,623,742), various skin disorders (U.S. patent application serial number 10/731973), motion sickness (U.S. patent application serial number 752,869), psoriasis and dermatitis (U.S. patent 5,670,484), injured muscles (U.S. patent 6,423,319) various cancers (U.S. patent 6,139,845), smooth muscle disorders (U.S. patent
15 5,437,291), down turned mouth corners (U.S. 6,358,917), nerve entrapment syndromes (U.S. patent application 2003 0224019), various impulse disorders (U.S. patent application serial number 423,380), acne (WO 03/011333) and neurogenic inflammation (U.S. patent 6,063,768). Controlled release toxin implants are known (see e.g. U.S. patents
20 6,306,423 and 6,312,708) as is transdermal botulinum toxin administration (U.S. patent application serial number 10/194,805).

Botulinum toxin type A has been used to treat epilepsia partialis continua, a type of focal motor epilepsy. Bhattacharya K., et al., *Novel
25 uses of botulinum toxin type A: two case reports*, Mov Disord 2000; 15(Suppl 2):51-52.

It is known that a botulinum toxin can be used to: weaken the chewing or biting muscle of the mouth so that self inflicted wounds and
30 resulting ulcers can heal (Payne M., et al, *Botulinum toxin as a novel treatment for self mutilation in Lesch-Nyhan syndrome*, Ann Neurol 2002 Sep;52(3 Supp 1):S157); permit healing of benign cystic lesions or

tumors (Blugerman G., et al., *Multiple eccrine hidrocystomas: A new therapeutic option with botulinum toxin*, Dermatol Surg 2003 May;29(5):557-9); treat anal fissure (Jost W., *Ten years' experience with botulinum toxin in anal fissure*, Int J Colorectal Dis 2002 Sep;17(5):298-302, and; treat certain types of atopic dermatitis (Heckmann M., et al., *Botulinum toxin type A injection in the treatment of lichen simplex: An open pilot study*, J Am Acad Dermatol 2002 Apr;46(4):617-9).

10 Additionally, a botulinum toxin may have an effect to reduce induced inflammatory pain in a rat formalin model. Aoki K., et al, *Mechanisms of the antinociceptive effect of subcutaneous Botox: Inhibition of peripheral and central nociceptive processing*, Cephalalgia 2003 Sep;23(7):649. Furthermore, it has been reported that botulinum toxin nerve blockage can cause a reduction of epidermal thickness. Li Y, et al., *Sensory and*
15 *motor denervation influences epidermal thickness in rat foot glabrous skin*, Exp Neurol 1997;147:452-462 (see page 459). Finally, it is known to administer a botulinum toxin to the foot to treat excessive foot sweating (Katsambas A., et al., *Cutaneous diseases of the foot: Unapproved treatments*, Clin Dermatol 2002 Nov-Dec;20(6):689-699;
20 Sevim, S., et al., *Botulinum toxin-A therapy for palmar and plantar hyperhidrosis*, Acta Neurol Belg 2002 Dec;102(4):167-70), spastic toes (Suputtitada, A., *Local botulinum toxin type A injections in the treatment of spastic toes*, Am J Phys Med Rehabil 2002 Oct;81(10):770-5), idiopathic toe walking (Tacks, L., et al., *Idiopathic toe walking: Treatment with botulinum toxin A injection*, Dev Med Child Neurol
25 2002;44(Suppl 91):6), and foot dystonia (Rogers J., et al., *Injections of botulinum toxin A in foot dystonia*, Neurology 1993 Apr;43(4 Suppl 2)).

30 Tetanus toxin, as well as derivatives (i.e. with a non-native targeting moiety), fragments, hybrids and chimeras thereof can also have therapeutic utility. The tetanus toxin bears many similarities to the botulinum toxins. Thus, both the tetanus toxin and the botulinum toxins

are polypeptides made by closely related species of *Clostridium* (*Clostridium tetani* and *Clostridium botulinum*, respectively).

Additionally, both the tetanus toxin and the botulinum toxins are dichain proteins composed of a light chain (molecular weight about 50 kD)

5 covalently bound by a single disulfide bond to a heavy chain (molecular weight about 100 kD). Hence, the molecular weight of tetanus toxin and of each of the seven botulinum toxins (non-complexed) is about 150 kD. Furthermore, for both the tetanus toxin and the botulinum toxins, the light chain bears the domain which exhibits intracellular biological
10 (protease) activity, while the heavy chain comprises the receptor binding (immunogenic) and cell membrane translocational domains.

Further, both the tetanus toxin and the botulinum toxins exhibit a high, specific affinity for ganglioside receptors on the surface of
15 presynaptic cholinergic neurons. Receptor mediated endocytosis of tetanus toxin by peripheral cholinergic neurons results in retrograde axonal transport, blocking of the release of inhibitory neurotransmitters from central synapses and a spastic paralysis. Contrarily, receptor mediated endocytosis of botulinum toxin by peripheral cholinergic
20 neurons results in little if any retrograde transport, inhibition of acetylcholine exocytosis from the intoxicated peripheral motor neurons and a flaccid paralysis.

Finally, the tetanus toxin and the botulinum toxins resemble each
25 other in both biosynthesis and molecular architecture. Thus, there is an overall 34% identity between the protein sequences of tetanus toxin and botulinum toxin type A, and a sequence identity as high as 62% for some functional domains. Binz T. et al., *The Complete Sequence of Botulinum Neurotoxin Type A and Comparison with Other Clostridial*
30 *Neurotoxins*, J Biological Chemistry 265(16);9153-9158:1990.

Acetylcholine

Typically only a single type of small molecule neurotransmitter is released by each type of neuron in the mammalian nervous system, although there is evidence which suggests that several neuromodulators can be released by the same neuron. The neurotransmitter

5 acetylcholine is secreted by neurons in many areas of the brain, but specifically by the large pyramidal cells of the motor cortex, by several different neurons in the basal ganglia, by the motor neurons that innervate the skeletal muscles, by the preganglionic neurons of the autonomic nervous system (both sympathetic and parasympathetic), by

10 the bag 1 fibers of the muscle spindle fiber, by the postganglionic neurons of the parasympathetic nervous system, and by some of the postganglionic neurons of the sympathetic nervous system. Essentially, only the postganglionic sympathetic nerve fibers to the sweat glands, the piloerector muscles and a few blood vessels are cholinergic as most of

15 the postganglionic neurons of the sympathetic nervous system secrete the neurotransmitter norepinephrine. In most instances acetylcholine has an excitatory effect. However, acetylcholine is known to have inhibitory effects at some of the peripheral parasympathetic nerve endings, such as inhibition of heart rate by the vagal nerve.

20

The efferent signals of the autonomic nervous system are transmitted to the body through either the sympathetic nervous system or the parasympathetic nervous system. The preganglionic neurons of the sympathetic nervous system extend from preganglionic sympathetic

25 neuron cell bodies located in the intermediolateral horn of the spinal cord. The preganglionic sympathetic nerve fibers, extending from the cell body, synapse with postganglionic neurons located in either a paravertebral sympathetic ganglion or in a prevertebral ganglion. Since, the preganglionic neurons of both the sympathetic and parasympathetic

30 nervous system are cholinergic, application of acetylcholine to the ganglia will excite both sympathetic and parasympathetic postganglionic neurons.

Acetylcholine activates two types of receptors, muscarinic and nicotinic receptors. The muscarinic receptors are found in all effector cells stimulated by the postganglionic, neurons of the parasympathetic nervous system as well as in those stimulated by the postganglionic cholinergic neurons of the sympathetic nervous system. The nicotinic receptors are found in the adrenal medulla, as well as within the autonomic ganglia, that is on the cell surface of the postganglionic neuron at the synapse between the preganglionic and postganglionic neurons of both the sympathetic and parasympathetic systems. Nicotinic receptors are also found in many nonautonomic nerve endings, for example in the membranes of skeletal muscle fibers at the neuromuscular junction.

Acetylcholine is released from cholinergic neurons when small, clear, intracellular vesicles fuse with the presynaptic neuronal cell membrane. A wide variety of non-neuronal secretory cells, such as, adrenal medulla (as well as the PC12 cell line) and pancreatic islet cells release catecholamines and parathyroid hormone, respectively, from large dense-core vesicles. The PC12 cell line is a clone of rat pheochromocytoma cells extensively used as a tissue culture model for studies of sympathoadrenal development. Botulinum toxin inhibits the release of both types of compounds from both types of cells *in vitro*, permeabilized (as by electroporation) or by direct injection of the toxin into the denervated cell. Botulinum toxin is also known to block release of the neurotransmitter glutamate from cortical synaptosomes cell cultures.

A neuromuscular junction is formed in skeletal muscle by the proximity of axons to muscle cells. A signal transmitted through the nervous system results in an action potential at the terminal axon, with activation of ion channels and resulting release of the neurotransmitter

acetylcholine from intraneuronal synaptic vesicles, for example at the motor endplate of the neuromuscular junction. The acetylcholine crosses the extracellular space to bind with acetylcholine receptor proteins on the surface of the muscle end plate. Once sufficient binding
5 has occurred, an action potential of the muscle cell causes specific membrane ion channel changes, resulting in muscle cell contraction. The acetylcholine is then released from the muscle cells and metabolized by cholinesterases in the extracellular space. The metabolites are recycled back into the terminal axon for reprocessing
10 into further acetylcholine.

What is needed therefore is an effective method for preventing headaches and for treating medication overuse disorders.

15 SUMMARY

The present invention meets this need and provides methods for effectively preventing headaches, treating pain and for treating medication overuse disorders (MOD), by local administration of a
20 Clostridial toxin.

A method according to our invention can be carried out by administration of a Clostridial toxin to a patient with a MOD. The Clostridial toxin used is preferably a botulinum toxin (as either a complex
25 or as a pure [i.e. about 150 kDa molecule], such as a botulinum toxin A, B, C, D, E, F or G. Administration of the Clostridial toxin can be by a transdermal route (i.e. by application of a Clostridial toxin in a cream, patch or lotion vehicle), subdermal route (i.e. subcutaneous or intramuscular), or intradermal route of administration.

30

A hypothesized physiological reason for the efficacy of our invention, as explained in greater detail below, is to reduce, inhibit or eliminate

sensory input (afferent) from the periphery into the central nervous system (including to the brain) which is perceived by the patient as pain and or which engenders development of a medication overuse disorder. Such pain sensory input can be attenuated or eliminated by targeting
5 subdermal sensory neurons with a low dose of a Clostridial toxin.

The dose of a Clostridial toxin used according to the present invention is less than the amount of Clostridial toxin (such as a botulinum toxin) that would be used to paralyze a muscle, since an
10 intent of a method according to the present invention is not to paralyze a muscle but to reduce a pain sensory output from sensory neurons located in or on a muscle, or in or under the skin.

The following definitions apply herein:
15

“About” means approximately or nearly and in the context of a numerical value or range set forth herein means $\pm 10\%$ of the numerical value or range recited or claimed.

20 “Alleviating” means a reduction in the occurrence of a pain, of a headache or of a symptom of a MOD. Thus, alleviating includes some reduction, significant reduction, near total reduction, and total reduction. An alleviating effect may not appear clinically for between 1 to 7 days after administration of a Clostridial toxin to a patient.

25 “Botulinum toxin” means a botulinum neurotoxin as either pure toxin or complex, and excludes botulinum toxins which are not neurotoxins such as the cytotoxic botulinum toxins C₂ and C₃.

30 “Local administration” means administration (i.e. by a subcutaneous, intramuscular, subdermal or transdermal route) of a pharmaceutical agent to or to the vicinity of a muscle or of a subdermal location or in the

head of a patient by a non-systemic route. Thus, local administration excludes systemic (i.e. to the blood circulation system) routes of administration, such as intravenous or oral administration. Peripheral administration means administration to the periphery (i.e. to a location
5 on or within a limb, trunk or head of a patient) as opposed to a visceral or gut (i.e. to the viscera) administration.

"Treating" means to alleviate (or to eliminate) at least one symptom of pain or of a MOD, either temporarily or permanently.

10

The Clostridial neurotoxin is administered in a therapeutically effective amount to alleviate pain, to prevent a headache or to treat a symptom of a MOD. A suitable Clostridial neurotoxin may be a neurotoxin made by a bacterium, for example, the neurotoxin may be
15 made from a *Clostridium botulinum*, *Clostridium butyricum*, or *Clostridium beratti*. In certain embodiments of the invention, the disorder can be treated by intramuscular (facial) administration a botulinum toxin to the patient. The botulinum toxin may be a botulinum toxin type A, type B, type C₁, type D, type E, type F, or type G. The pain
20 and/or MOD alleviating effects of the botulinum toxin may persist for between about 1 month and 5 years. The botulinum neurotoxin can be a recombinantly made botulinum neurotoxins, such as botulinum toxins produced by *E. coli*. In addition or alternatively, the botulinum neurotoxin can be a modified neurotoxin, that is a botulinum neurotoxin
25 which has at least one of its amino acids deleted, modified or replaced, as compared to a native or the modified botulinum neurotoxin can be a recombinant produced botulinum neurotoxin or a derivative or fragment thereof.

30 A method for treating a MOD according to the present invention can comprise the step of local administration of a botulinum toxin to a patient with a MOD to thereby alleviate the MOD. The botulinum toxin can be

selected from the group consisting of botulinum toxin types A, B, C, D, E, F and G. Botulinum toxin type A is a preferred botulinum toxin. The botulinum toxin can be administered in an amount of between about 1 unit and about 3,000 units and the alleviation of the MOD can persist for
5 between about 1 month and about 5 years. The local administration of the botulinum toxin can be to or to a vicinity of where the patient experiences or is predisposed to experience pain. Alternately, the local administration can be by intramuscular injection or to a subdermal location from which the patient perceives the existence of a pain to
10 arise, typically at the forehead.

DRAWINGS

15 The following drawings are presented to assist understanding of aspects and features of the present invention.

Figure 1 is a graph which shows results (mean change in the number of headaches per thirty day period) of a clinical study carried out for use
20 of BOTOX to *inter alia* treat migraine headache, showing that the patients had fewer headaches after administration of BOTOX. In all the data shown in all the Figures the patients had been administered BOTOX at days 0, 90 and 180.

25 Figure 2 is a graph which shows results (mean change in the number of days when the patients were concurrently taking acute headache pain alleviation medication per thirty day period) of a clinical study carried out for use of BOTOX to *inter alia* treat migraine headache, showing that the patients had fewer days when they were taking acute headache pain
30 alleviation medication after administration of BOTOX.

Figure 3 is a graph which shows a comparison of the percent of patients (some who had been administered BOTOX and some who had been administered a placebo) who were over a thirty day period using narcotics medication to control acute headache pain. Figure 3 shows a decrease in narcotics use in the BOTOX treated patients.

Figure 4 is a graph which shows results that there was a decrease in the percent of patients who had acute headache medication overuse in a thirty day period after administration of BOTOX.

Figure 5 is a graph which shows that there was a decrease in the percent of patients who had triptans acute headache medication overuse in a thirty day period after administration of BOTOX.

15

DESCRIPTION

The present invention is based on the discovery that a botulinum toxin can be used to treat a patient who is overusing a pain alleviation medication to treat his or her pain (such as a headache pain), to reduce both (a) the number of headaches experienced by the patient (see Figure 1) and (b) the daily use of acute headache pain medication by the patient (Figure 2). In particular we have found (see Figure 3) that a botulinum toxin can be used to reduce use by patients of narcotic pain medication. Medication overuse to treat headache pain ("MOH") is a recognized disorder.

Additionally, we found that use of a botulinum toxin in patients who were overusing pain alleviation medication experienced a significant reduction in their use of such medications after treatment with a botulinum toxin (see Figure 4). We also found that there was a

significant reduction in the intake of triptan medications in triptan medication overuse patients (see Figure 5).

Our invention can also be used as part of a detoxification protocol
5 whereby a patient who is being weaned off acute pain medications is facilitated in this goal by concurrent administration of a botulinum toxin. Our invention can also be used to treat other chronic pain conditions (e.g. back pain, neuropathic pain, allodynia, fibromyalgia, etc.) which can include patients that overuse acute medications,
10 specifically narcotics and triptans.

According to our invention, a medication overuse disorder can be treated by local administration of a therapeutically effective amount of a botulinum toxin. Thus, a botulinum toxin (such as a botulinum toxin
15 serotype A, B, C₁, D, E, F or G) can be injected (i.e. intramuscular injection) into or in the vicinity where a patient is experiencing the pain to thereby suppress the pain or prevent it's occurrence. Alternately, the botulinum toxin can be administered to an intradermal or subdermal pain sensory neuron thereby suppressing and treating such a medication
20 overuse disorder.

Our invention is preferably practised by administering a botulinum toxin directly to a location where a patient is or is predisposed to experience pain. Without wishing to be bound by theory a physiological
25 mechanism can be proposed for the efficacy of the present invention. It is known that muscles have a complex system of innervation and sensory output. Thus, anterior motor neurons located in each segment of the anterior horns of the spinal cord gray matter give rise to efferent alpha motor neurons and efferent gamma motor neurons that leave the
30 spinal cord by way of the anterior roots to innervate skeletal (extrafusal) muscle fibers. The alpha motor neurons cause contraction of extrafusal skeletal muscle fibers while the gamma motor neurons innervate the

intrafusal fibers of skeletal muscle. As well as excitation by these two type of efferent anterior motor neuron projections, there are additional, afferent sensory neurons which project from muscle spindle and golgi tendon organs and act to transmit information regarding various muscle parameter status to the spinal cord, cerebellum and cerebral cortex. These afferent motor neurons which relay sensory information from the muscle spindle include type Ia and type II sensory afferent neurons. See e.g. pages 686-688 of Guyton A.C. et al., *Textbook of Medical Physiology*, W.B. Saunders Company 1996, ninth edition.

10

Significantly, it has been determined that a botulinum toxin can act to reduce transmission of sensory information from muscle type Ia afferent neurons. Aoki, K., *Physiology and pharmacology of therapeutic botulinum neurotoxins*, in Kreyden, O., editor, *Hyperhydrosis and botulinum toxin in dermatology*, Basel, Karger; 2002; 30: pages 107-116, at 109-110. And it has been hypothesized that botulinum toxin can have a direct effect upon muscle cell sensory afferents and modify signals from these afferents to the central nervous system. See e.g. Brin, M., et al., *Botulinum toxin type A: pharmacology*, in Mayer N., editor, *Spasticity: etiology, evaluation, management and the role of botulinum toxin*, 2002; pages 110-124, at 112-113; Cui, M., et al., *Mechanisms of the antinociceptive effect of subcutaneous BOTOX®: inhibition of peripheral and central nociceptive processing*, Naunyn Schmiedebergs Arch Pharmacol 2002; 365 (supp 2): R17; Aoki, K., et al., *Botulinum toxin type A and other botulinum toxin serotypes: a comparative review of biochemical and pharmacological actions*, Eur J. Neurol 2001: (suppl 5); 21-29. Thus, it has been demonstrated that botulinum toxin can cause an altered sensory output from muscle to CNS and brain.

30

Importantly, the sensory neurons from which afferent output is to be inhibited by a method according to the present invention need not be

located on or within a muscle, but can be in an intradermal or subdermal location.

Thus, pain can be due to sensory input from afferent facial area
5 neurons. Administration of a botulinum toxin to a facial muscles or skin to reduce sensory output from the muscle can result in alleviation of and prevention of pain.

It is our hypothesis, as may be the case in the treatment of a
10 migraine headache with a botulinum toxin, that signals transmitted by afferent pain nerves in or on muscle tissue (i.e. muscle spindle fibers and muscle pain fibers) or as a part of sensory structures in the skin or subdermally induce the pain sensation. That is, afferent signal from muscles or skin structures provide sensory information to the brain
15 which then leads to the generation of pain. Thus, a local administration of a botulinum toxin to muscle spindle fibers, pain fibers or other sensors in or in the vicinity of a muscle can act to alter the neural signal afferent output from these muscles to the brain and thereby decrease the sensation of pain..

20 Important elements of invention are firstly that is practised by use of a local administration of low dose of a botulinum toxin. The selected low dose does not cause a muscle paralysis. Secondly, the invention is practised by local administration of the low dose of the botulinum toxin
25 to the muscle or to the muscle group which initiates the pain sensation.

The amount of the Clostridial toxin administered according to a method within the scope of the disclosed invention can vary according to the particular characteristics of the pain being treated, including its
30 severity and other various patient variables including size, weight, age, and responsiveness to therapy. To guide the practitioner, typically, no less than about 1 unit and no more than about 25 units of a botulinum

toxin type A (such as BOTOX[®]) is administered per injection site (i.e. to each muscle portion injected), per patent treatment session. For a botulinum toxin type A such as DYSPORT[®], no less than about 2 units and no more about 125 units of the botulinum toxin type A are
5 administered per injection site, per patent treatment session. For a botulinum toxin type B such as MYOBLOC[®], no less than about 40 units and no more about 1500 units of the botulinum toxin type B are administered per injection site, per patent treatment session. Less than about 1, 2 or 40 units (of BOTOX[®], DYSPORT[®] and MYOBLOC[®]
10 respectively) can fail to achieve a desired therapeutic effect, while more than about 25, 125 or 1500 units (of BOTOX[®], DYSPORT[®] and MYOBLOC[®] respectively) can result in significant muscle hypotonicity, weakness and/or paralysis.

15 More preferably: for BOTOX[®] no less than about 2 units and no more about 20 units of a botulinum toxin type A; for DYSPORT[®] no less than about 4 units and no more than about 100 units, and; for MYOBLOC[®], no less than about 80 units and no more than about 1000 units are, respectively, administered per injection site, per patent treatment
20 session.

Most preferably: for BOTOX[®] no less than about 5 units and no more about 15 units of a botulinum toxin type A; for DYSPORT[®] no less than about 20 units and no more than about 75 units, and; for MYOBLOC[®],
25 no less than about 200 units and no more than about 750 units are, respectively, administered per injection site, per patent treatment session. It is important to note that there can be multiple injection sites (i.e. a pattern of injections) for each patient treatment session.

30 Although examples of routes of administration and dosages are provided, the appropriate route of administration and dosage are

generally determined on a case by case basis by the attending physician. Such determinations are routine to one of ordinary skill in the art (see for example, *Harrison's Principles of Internal Medicine* (1998), edited by Anthony Fauci et al., 14th edition, published by McGraw Hill).

5 For example, the route and dosage for administration of a neurotoxin according to the present disclosed invention can be selected based upon criteria such as the solubility characteristics of the neurotoxin chosen as well as the intensity of pain perceived.

10 The present invention is based on the discovery that local administration of a Clostridial toxin can provide significant and long lasting relief and prevention of pain and treatment of a medication overuse disorder. The Clostridial toxins used in accordance with the invention disclosed herein can inhibit transmission of chemical or
15 electrical signals between select neuronal groups that are involved in generation of pain. The Clostridial toxins preferably are not cytotoxic to the cells that are exposed to the Clostridial toxin. The Clostridial toxin can inhibit neurotransmission by reducing or preventing exocytosis of neurotransmitter from the neurons exposed to the Clostridial toxin. Or
20 the applied Clostridial toxin can reduce neurotransmission by inhibiting the generation of action potentials of the neurons exposed to the toxin. The headache and headache pain prevention and alleviation effects provided by the Clostridial toxin can persist for a relatively long period of time, for example, for more than two months, and potentially for several
25 years.

Examples of Clostridial toxins within the scope of the present invention include neurotoxins made by *Clostridium botulinum*, *Clostridium butyricum* and *Clostridium beratti* species. In addition, the
30 botulinum toxins used in the methods of the invention may be a botulinum toxin selected from a group of botulinum toxin types A, B, C, D, E, F, and G. In one embodiment of the invention, the botulinum

neurotoxin administered to the patient is botulinum toxin type A. Botulinum toxin type A is desirable due to its high potency in humans, ready availability, and known use for the treatment of skeletal and smooth muscle disorders when locally administered by intramuscular injection. The present invention also includes the use of (a) Clostridial neurotoxins obtained or processed by bacterial culturing, toxin extraction, concentration, preservation, freeze drying, and/or reconstitution; and/or (b) modified or recombinant neurotoxins, that is neurotoxins that have had one or more amino acids or amino acid sequences deliberately deleted, modified or replaced by known chemical/biochemical amino acid modification procedures or by use of known host cell/recombinant vector recombinant technologies, as well as derivatives or fragments of neurotoxins so made. These neurotoxin variants retain the ability to inhibit neurotransmission between or among neurons, and some of these variants may provide increased durations of inhibitory effects as compared to native neurotoxins, or may provide enhanced binding specificity to the neurons exposed to the neurotoxins. These neurotoxin variants may be selected by screening the variants using conventional assays to identify neurotoxins that have the desired physiological effects of inhibiting neurotransmission.

Botulinum toxins for use according to the present invention can be stored in lyophilized, vacuum dried form in containers under vacuum pressure or as stable liquids. Prior to lyophilization the botulinum toxin can be combined with pharmaceutically acceptable excipients, stabilizers and/or carriers, such as albumin. The lyophilized material can be reconstituted with saline or water to create a solution or composition containing the botulinum toxin to be administered to the patient.

Although the composition may only contain a single type of neurotoxin, such as botulinum toxin type A, as the active ingredient to

suppress neurotransmission, other therapeutic compositions may include two or more types of neurotoxins, which may provide enhanced therapeutic treatment of a headache. For example, a composition administered to a patient may include botulinum toxin type A and
5 botulinum toxin type B. Administering a single composition containing two different neurotoxins may permit the effective concentration of each of the neurotoxins to be lower than if a single neurotoxin is administered to the patient while still achieving the desired therapeutic effects. The composition administered to the patient may also contain other
10 pharmaceutically active ingredients, such as, protein receptor or ion channel modulators, in combination with the neurotoxin or neurotoxins. These modulators may contribute to the reduction in neurotransmission between the various neurons. For example, a composition may contain gamma aminobutyric acid (GABA) type A receptor modulators that
15 enhance the inhibitory effects mediated by the GABA_A receptor. The GABA_A receptor inhibits neuronal activity by effectively shunting current flow across the cell membrane. GABA_A receptor modulators may enhance the inhibitory effects of the GABA_A receptor and reduce electrical or chemical signal transmission from the neurons. Examples
20 of GABA_A receptor modulators include benzodiazepines, such as diazepam, oxaxepam, lorazepam, prazepam, alprazolam, halazepam, chlordiazepoxide, and chlorazepate. Compositions may also contain glutamate receptor modulators that decrease the excitatory effects mediated by glutamate receptors. Examples of glutamate receptor
25 modulators include agents that inhibit current flux through AMPA, NMDA, and/or kainate types of glutamate receptors. The compositions may also include agents that modulate dopamine receptors, such as antipsychotics, norepinephrine receptors, and/or serotonin receptors. The compositions may also include agents that affect ion flux through
30 voltage gated calcium channels, potassium channels, and/or sodium channels. Thus, the compositions used to treat pain can include one or

more neurotoxins, such as botulinum toxins, in addition to ion channel receptor modulators that may reduce neurotransmission.

The neurotoxin may be administered by any suitable method as
5 determined by the attending physician. The methods of administration permit the neurotoxin to be administered locally to a selected target tissue. Methods of administration include injection of a solution or composition containing the neurotoxin, as described above, and include
10 implantation of a controlled release system that controllably releases the neurotoxin to the target tissue. Such controlled release systems reduce the need for repeat injections. Diffusion of biological activity of a botulinum toxin within a tissue appears to be a function of dose and can be graduated. Jankovic J., et al *Therapy With Botulinum Toxin*, Marcel
15 Dekker, Inc., (1994), page 150. Thus, diffusion of botulinum toxin can be controlled to reduce potentially undesirable side effects that may affect the patient's cognitive abilities. For example, the neurotoxin can be administered so that the neurotoxin primarily effects neural systems believed to be involved in the generation of pain and/or inflammation, and does not have negatively adverse effects on other neural systems.

20

A polyanhydride polymer, Gliadel® (Stolle R & D, Inc., Cincinnati, OH) a copolymer of poly-carboxyphenoxyp propane and sebacic acid in a ratio of 20:80 has been used to make implants, and has been intracranially
25 implanted to treat malignant gliomas. Polymer and BCNU can be co-dissolved in methylene chloride and spray-dried into microspheres. The microspheres can then be pressed into discs 1.4 cm in diameter and 1.0 mm thick by compression molding, packaged in aluminum foil pouches under nitrogen atmosphere and sterilized by 2.2 megaRads of gamma irradiation. The polymer permits release of carmustine over a 2-3 week
30 period, although it can take more than a year for the polymer to be largely degraded. Brem, H., et al, *Placebo-Controlled Trial of Safety and Efficacy of Intraoperative Controlled Delivery by Biodegradable*

Polymers of Chemotherapy for Recurrent Gliomas, Lancet 345;1008-1012:1995.

Implants useful in practicing the methods disclosed herein may be prepared by mixing a desired amount of a stabilized neurotoxin (such as non-reconstituted BOTOX®) into a solution of a suitable polymer dissolved in methylene chloride. The solution may be prepared at room temperature. The solution can then be transferred to a Petri dish and the methylene chloride evaporated in a vacuum desiccator. Depending upon the implant size desired and hence the amount of incorporated neurotoxin, a suitable amount of the dried neurotoxin incorporating implant is compressed at about 8000 p.s.i. for 5 seconds or at 3000 p.s.i. for 17 seconds in a mold to form implant discs encapsulating the neurotoxin. See e.g. Fung L. K. et al., *Pharmacokinetics of Interstitial Delivery of Carmustine 4-Hydroperoxycyclophosphamide and Paclitaxel From a Biodegradable Polymer Implant in the Monkey Brain*, Cancer Research 58;672-684:1998.

Local administration of a Clostridial toxin, such as a botulinum toxin, can provide a high, local therapeutic level of the toxin. A controlled release polymer capable of long term, local delivery of a Clostridial toxin to a target muscle permits effective dosing of a target tissue. A suitable implant, as set forth in U.S. patent number 6,306,423 entitled "Neurotoxin Implant", allows the direct introduction of a chemotherapeutic agent to a target tissue via a controlled release polymer. The implant polymers used are preferably hydrophobic so as to protect the polymer incorporated neurotoxin from water induced decomposition until the toxin is released into the target tissue environment.

30

Local administration of a botulinum toxin, according to the present invention, by injection or implant to a target tissue provides a superior

alternative to systemic administration of pharmaceuticals to patients to alleviate pain and to treat a MOD such as MOH.

5 The amount of a Clostridial toxin selected for local administration to a target tissue according to the present disclosed invention can be varied based upon criteria such as the severity of the pain or type of headache or MOD being treated, the extent of muscle tissue to be treated, solubility characteristics of the neurotoxin toxin chosen as well as the age, sex, weight and health of the patient. For example, the extent of
10 the area of muscle tissue influenced is believed to be proportional to the volume of neurotoxin injected, while the quantity of the suppressant effect is, for most dose ranges, believed to be proportional to the concentration of a Clostridial toxin administered. Methods for determining the appropriate route of administration and dosage are
15 generally determined on a case by case basis by the attending physician. Such determinations are routine to one of ordinary skill in the art (see for example, *Harrison's Principles of Internal Medicine* (1998), edited by Anthony Fauci et al., 14th edition, published by McGraw Hill).

20 Significantly, a method within the scope of the present invention can provide improved patient function. "Improved patient function" can be defined as an improvement measured by factors such as a reduced pain, reduced time spent in bed, increased ambulation, healthier attitude, more varied lifestyle and/or healing permitted by normal muscle
25 tone. Improved patient function is synonymous with an improved quality of life (QOL). QOL can be assessed using, for example, the known SF-12 or SF-36 health survey scoring procedures. SF-36 assesses a patient's physical and mental health in the eight domains of physical functioning, role limitations due to physical problems, social functioning,
30 bodily pain, general mental health, role limitations due to emotional problems, vitality, and general health perceptions. Scores obtained can

be compared to published values available for various general and patient populations.

EXAMPLES

5 The following non-limiting examples provide those of ordinary skill in the art with specific preferred methods to treat conditions within the scope of the present invention and are not intended to limit the scope of the invention. In the following examples various modes of non-systemic administration of a Clostridial neurotoxin can be carried out. For
10 example, by intramuscular injection, subcutaneous injection or by implantation of a controlled release implant.

Example 1

Botulinum Toxin Type A Therapy for a Medication Overuse Headache Disorder

15

A clinical study was carried out which included patients who complained of headache pain and who took frequent acute pain medications, such as narcotics and triptans to control the pain. These
20 patients were diagnosed with medication overuse headache (MOH) disorder. A botulinum toxin (BOTOX) was administered to these patients at three times during the clinical study: at day 0, at day 90 and at day 180. The BOTOX injections were administered intramuscularly in an average of 20 separate injections to each patient at each of the
25 three injection sessions. The BOTOX was administered to seven different muscles (i.e. 20 total injections into 7 muscles). From 105 to 260 units of the BOTOX was administered to each patient at each of the three treatment sessions. It was found that they experienced a reduction in both (a) the number of headaches experienced by such
30 patients (Figure 1), and; (b) the daily use of acute headache pain medication by these patients (Figure 2). In particular it was found

(Figure 3) that a botulinum toxin can be used to reduce use by these patients of narcotic pain medication.

5 Additionally, it was found that use of a botulinum toxin in patients who were overusing pain alleviation medication resulted in a significant reduction in their use of such medications after treatment with a botulinum toxin (see Figure 4). It was also found that there was a significant reduction in the intake of triptan medications in overuse patients (Figure 5). Thus, this clinical study surprisingly showed that a
10 botulinum toxin can be used to treat a medication overuse headache disorder (MOH).

A botulinum toxin type B, C, D, E, F or G can be substituted for the botulinum toxin type A used above, for example by use of 250 units of a
15 botulinum toxin type B.

Although the present invention has been described in detail with regard to certain preferred methods, other embodiments, versions, and modifications within the scope of the present invention are possible. For
20 example, a wide variety of neurotoxins can be effectively used in the methods of the present invention. Additionally, the present invention includes local administration methods to alleviate a headache pain or to reduce the number of headaches wherein two or more neurotoxins, such as two or more botulinum toxins, are administered concurrently or
25 consecutively. For example, botulinum toxin type A can be administered until a loss of clinical response or neutralizing antibodies develop, followed by administration of botulinum toxin type B. Alternately, a combination of any two or more of the botulinum serotypes A-G can be locally administered to control the onset and duration of the desired
30 therapeutic result. Furthermore, non-neurotoxin compounds can be administered prior to, concurrently with or subsequent to administration of the neurotoxin to provide adjunct effect such as enhanced or a more

rapid onset of denervation before the neurotoxin, such as a botulinum toxin, begins to exert its therapeutic effect.

A method for treating a disorder according to the invention disclosed
5 herein has many benefits and advantages, including the following:

1. Headaches can be eliminated.
2. symptoms of pain, such as a headache pain can be dramatically
10 reduced or eliminated.
3. the symptoms of a pain can be reduced or eliminated for at least about two to about six months per injection of neurotoxin and for from about one year to about five years upon use of a controlled release
15 neurotoxin implant.
4. headaches can be eliminated for at least about two to about six months per injection of neurotoxin and for from about one year to about five years.
20
5. a medication overuse disorder, such as MOH, can be effectively treated.

Although the present invention has been described in detail with
25 regard to certain preferred methods, other embodiments, versions, and modifications within the scope of the present invention are possible. For example, a wide variety of neurotoxins can be effectively used in the methods of the present invention. Additionally, the present invention includes local administration methods wherein two or more Clostridial
30 neurotoxins, such as two or more botulinum toxins, are administered concurrently or consecutively. For example, botulinum toxin type A can be locally administered until a loss of clinical response or neutralizing

antibodies develop, followed by administration of botulinum toxin type B. Furthermore, non-neurotoxin compounds can be locally administered prior to, concurrently with or subsequent to administration of the neurotoxin to provide adjunct effect such as enhanced or a more rapid
5 onset of pain suppression before the neurotoxin, such as a botulinum toxin, begins to exert its more long lasting pain and MOH suppressant effect.

Our invention also includes within its scope the use of a neurotoxin,
10 such as a botulinum toxin, in the preparation of a medicament for the treatment of a medication overuse disorder, by local administration of the Clostridial neurotoxin.

All references, articles, patents, applications and publications set
15 forth above are incorporated herein by reference in their entireties.

Accordingly, the spirit and scope of the following claims should not be limited to the descriptions of the preferred embodiments set forth above.